AP Biology - Big Idea 3 Organisms Store, Receive, Transmit & Respond to Information

Unit 3A

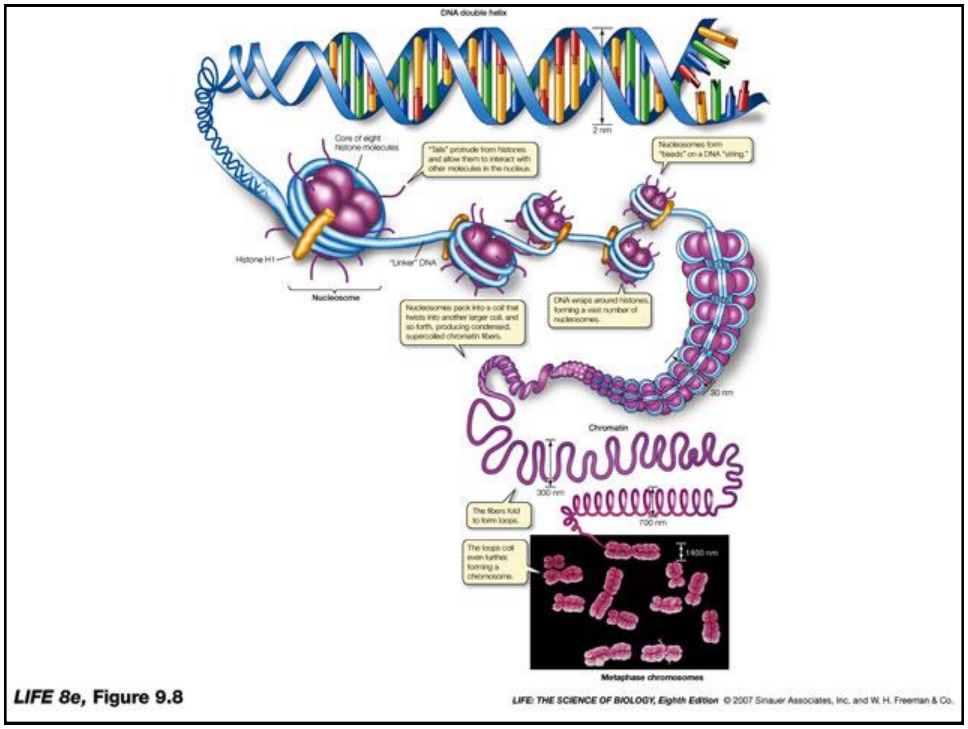
The Molecular Basis of Heredity – Storing Genetic Information

DNA & RNA

- DNA (and sometimes RNA) is the primary source of heritable information.
- These are molecules with properties suited to their function.

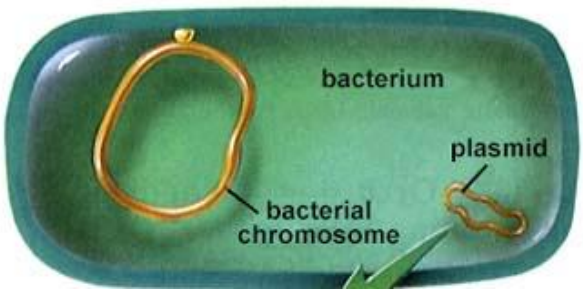
Chromosomes are DNA!!!

- Eukaryotes have multiple linear chromosomes.
- Prokaryotes & Viruses have circular chromosomes.



Plasmids

- Small, circular DNA molecules, separate from chromosome(s)
  - Viruses, Bacteria, Eukaryotes (yeasts)



How do we know about DNA?

Research the following scientists & significance to DNA history. In a hand-written essay or poster:

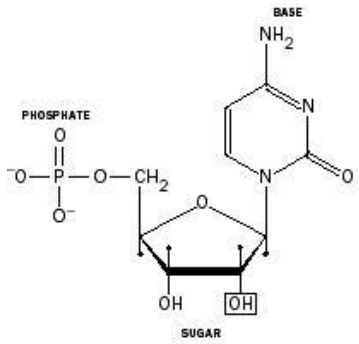
- Describe methods used, Major findings, & how they contributed proof that DNA is the carrier of genetic information.

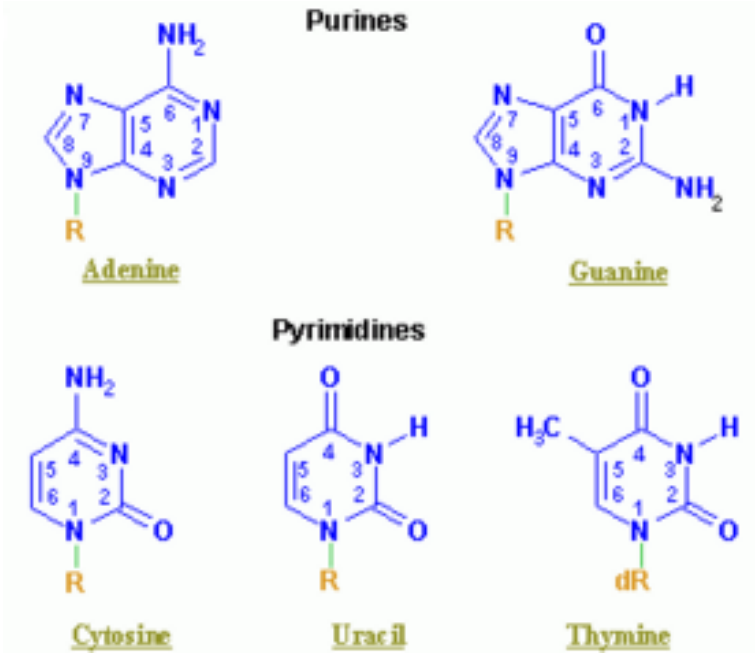
1. James Watson & Francis Crick, Maurice Wilkins, Rosalind Franklin
2. Avery, MacLeod & McCarty experiments
3. Hershey-Chase experiment

Building Blocks

Nucleotides

All have a phosphate, 5-carbon sugar, and a nitrogen base.



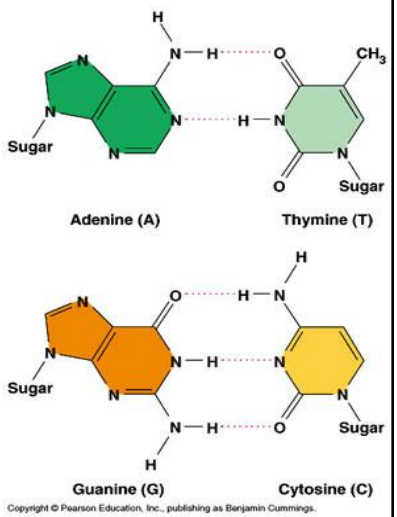


DNA Structure

Base pairing

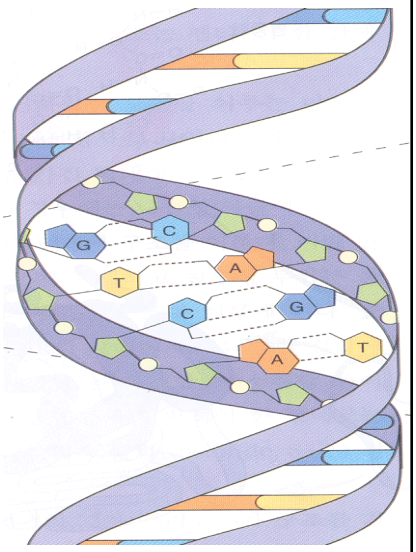
1. Adenine pairs with Thymine
   -2 Hydrogen bonds
2. Guanine pairs with Cytosine
   -3 Hydrogen bonds

MORE STABLE!



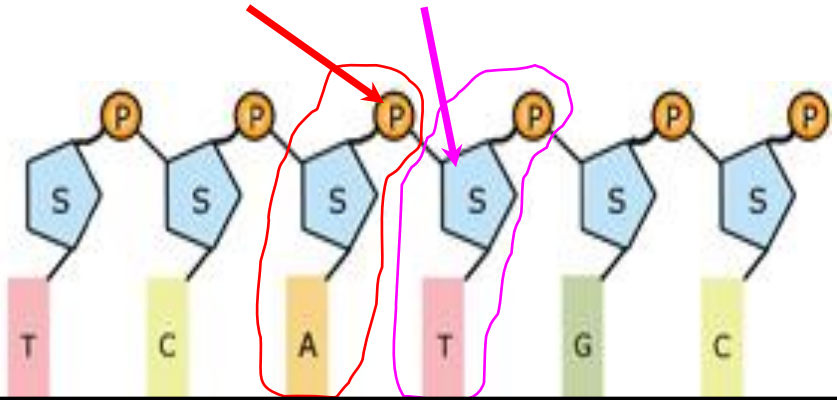
DNA Structure

- 2 single strands wrapped around each other = **double helix**.
- Held together **by H bonding** between bases (A-T, G-C)
- Sugars + Phosphates **perpendicular** to bases.



DNA Structure

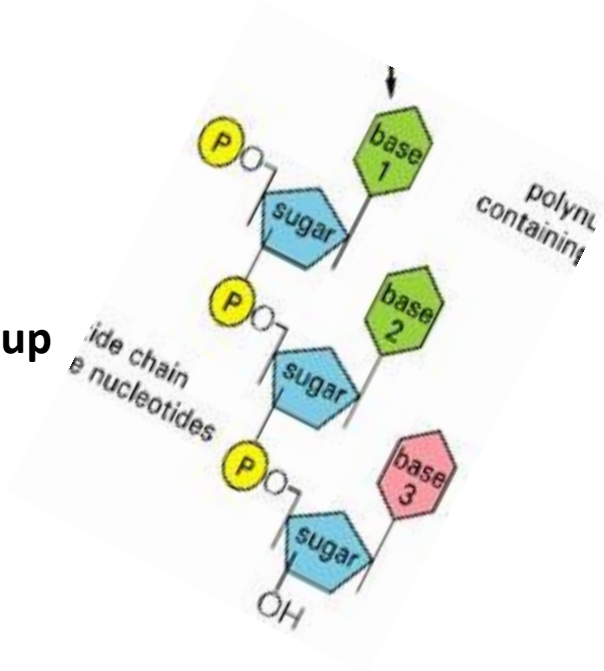
2. Joining nucleotides
   a. **Phosphate (5')** of 1 + **sugar** (3') of another



DNA Structure

3’ = end with exposed hydroxyl group

5’ = end with exposed phosphate group



DNA Structure

3’ = end with exposed hydroxyl group

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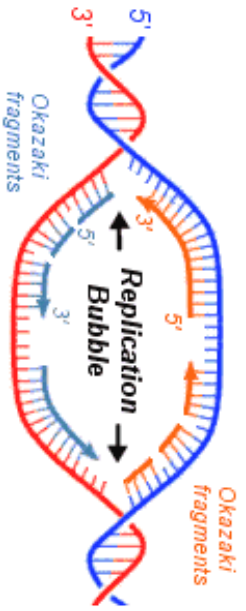
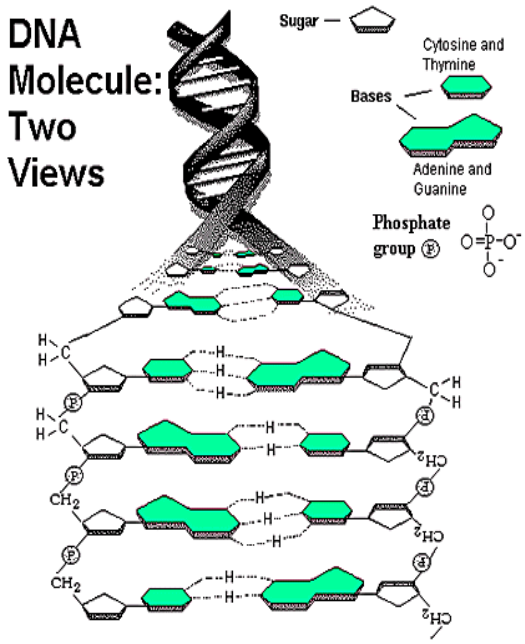


DNA Structure

Anti parallel:

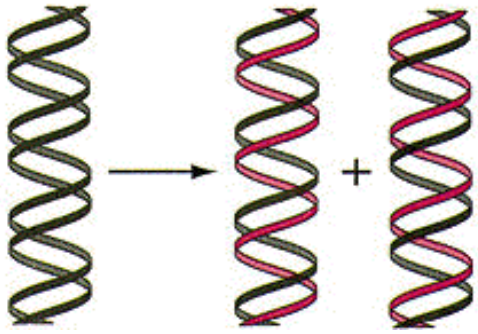
Strands run in opposite directions



DNA Replication

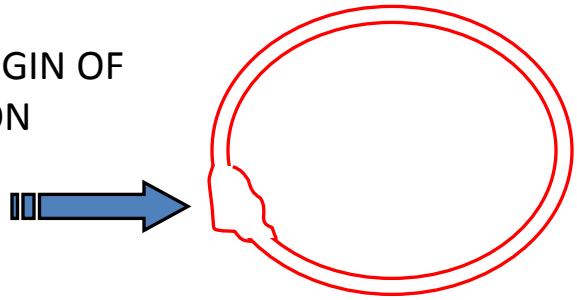
Semi-conservative replication model

a. Each **new** DNA double helix has **one old** strand and **one new** strand



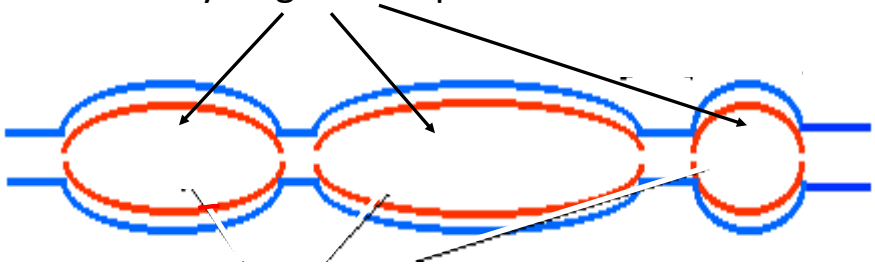
D. DNA Replication

1. Prokaryotes
   a. **Circular** DNA
   b. **Starts** at a **single place**
      *Single ORIGIN OF REPLICATION



D. DNA Replication

2. Eukaryotes
   a. **Linear** DNA (Straight line)
   b. Starts at **many** places
      * many origins of replication

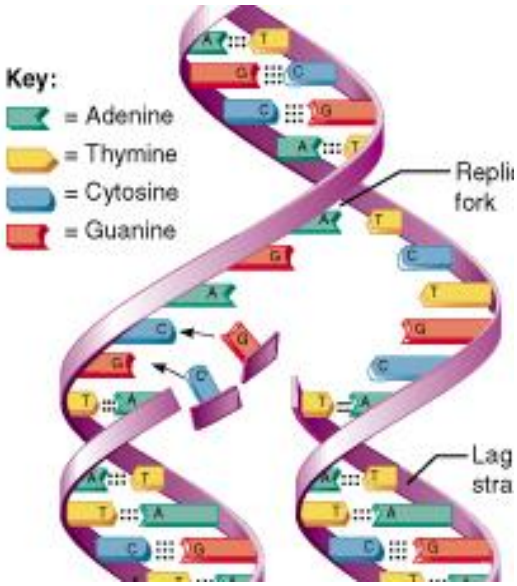


D. DNA Replication

3. How it happens:

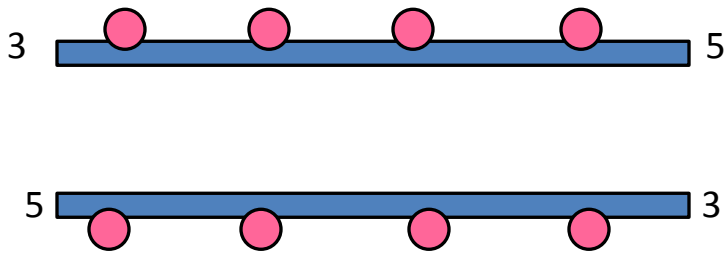
a. The **2** strands **separate: Helicase**

b. **Each strand** becomes a **template** to build from.



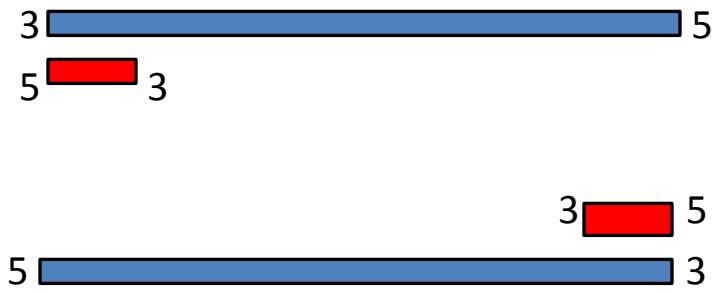
Separating the DNA

2 strands must be held apart



Primers

Nucleotides must build on existing template, so a **Primer** is created



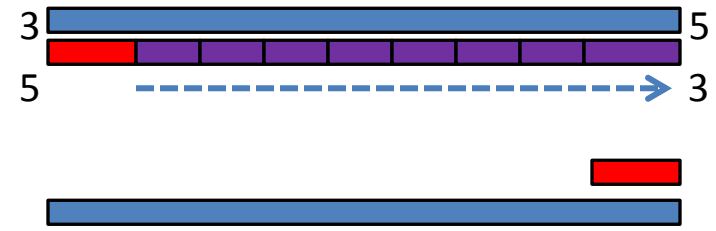
Leading Strand

Strand that will grow **continuously**

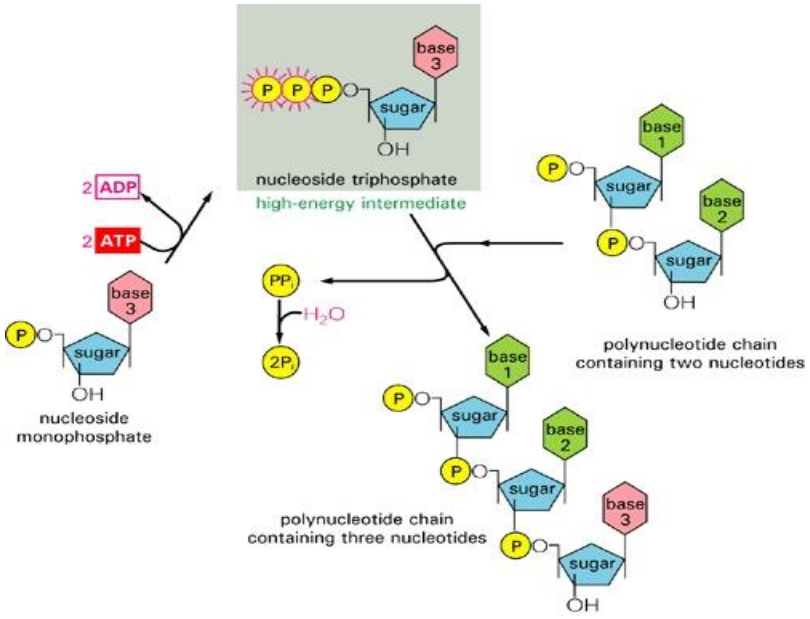
because there is always a free OH to add onto.

Elongates in the **5' → 3'** Direction

DNA Polymerase adds nucleotides using energy from Dephosphorylation of nucleoside triphosphate



Polymerization

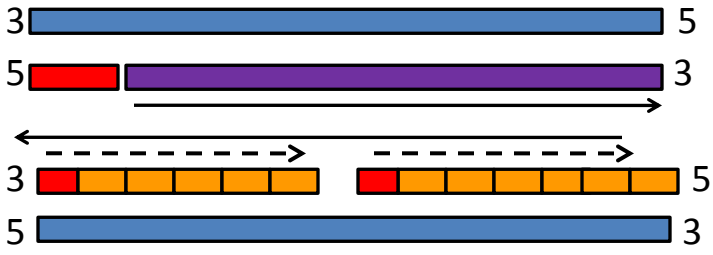


Lagging Strand

Strand that will grow **discontinuously**

because a new primer must add to yield a free OH group.

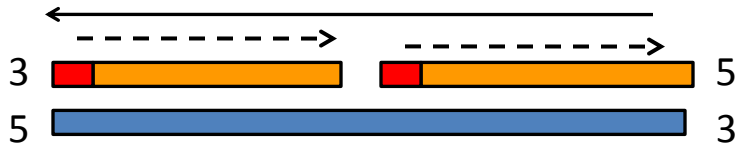
Elongates in the **5' → 3'** Direction *overall*



Lagging Strand

Each segment = Okazaki Fragment

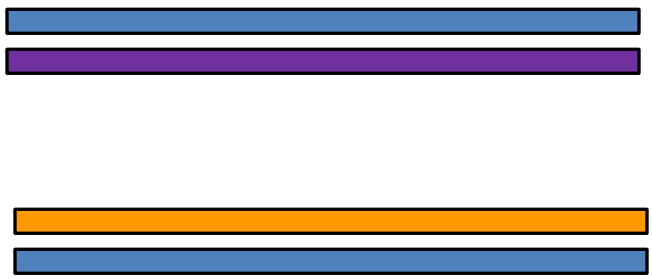
Fragments synthesized & linked by DNA polymerase

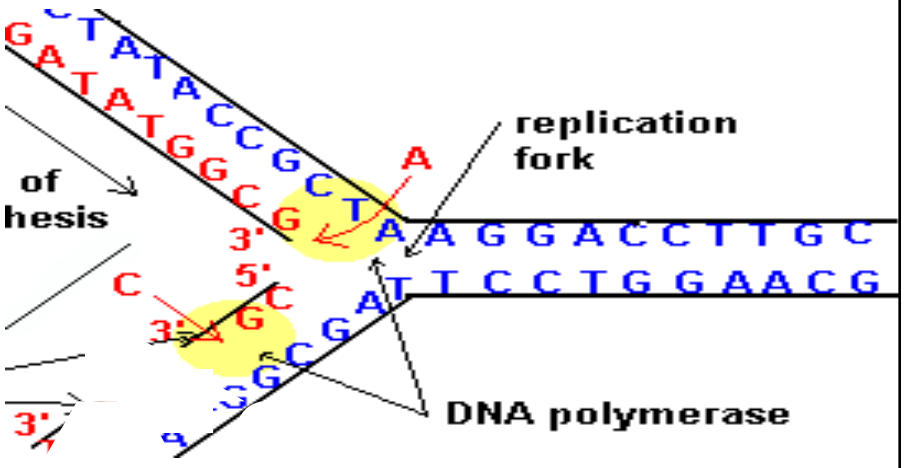


Removing the Primers

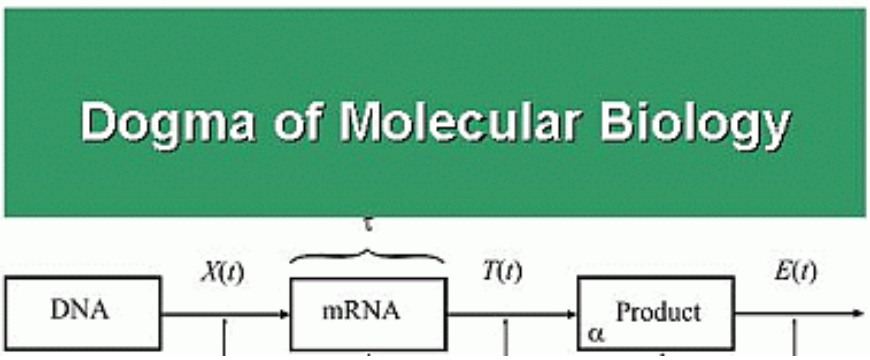
RNA Primers are replaced by DNA

All segments joined by **DNA Ligase**.





Using the DNA: Protein Synthesis



E. The Information

- The DNA structure shows how it **copies** itself.
- It does not show how it's **information** is **used**.
- DNA is like a **library** = Information **waiting** to be used!

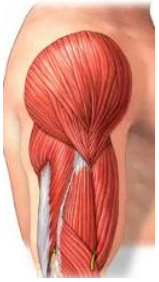
E. The Information

1. What is the information?

   Instructions to make proteins.

2. Why is this so important?

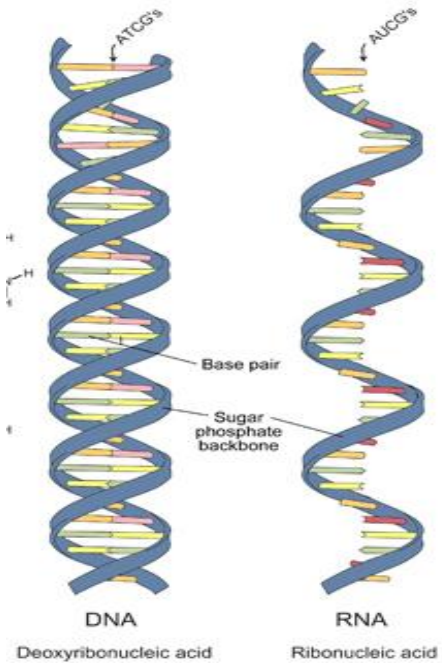
   Phenotypes are determined by protein products & their activities!



F. RNA

RNA is different from **DNA**:

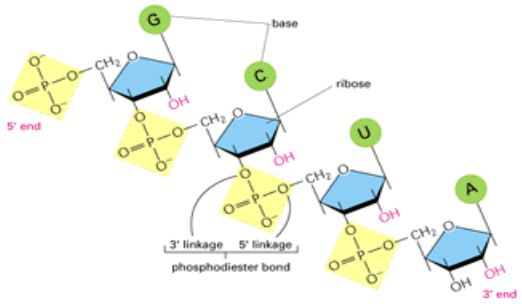
a. **Single** helix

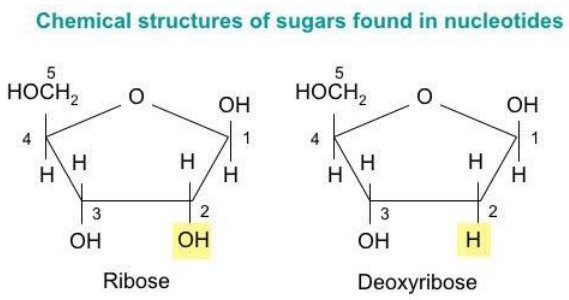


F. RNA

RNA is different from DNA:

b. Sugar = **Ribose** (not deoxyribose)



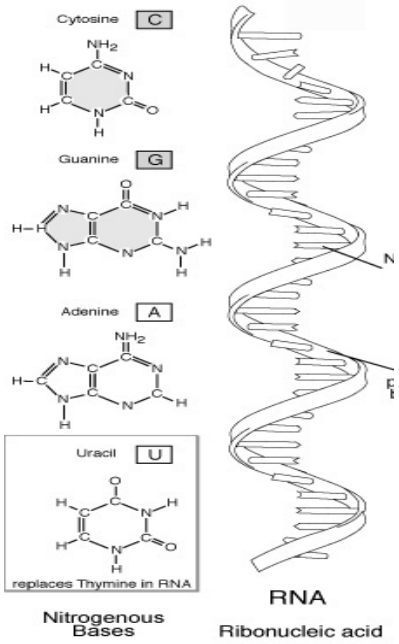


F. RNA

RNA is different from DNA:

c. NO **THYMINE**!

Uracil instead,
pairs with **Adenine**



What are the similarities between DNA & RNA?

F. RNA

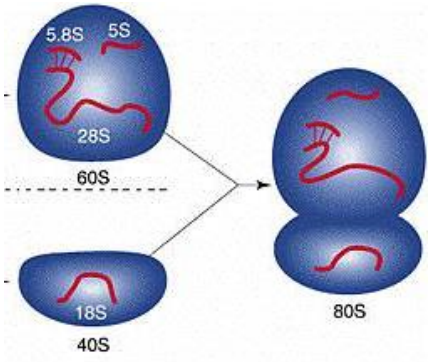
2. **3 Types** of RNA

a. **Messenger** RNA (**mRNA**)

Serve as "messengers" that **carry** a **copy** of **instructions**. Made during **transcription**.

F. RNA

b. **Ribosomal** RNA (**rRNA**)

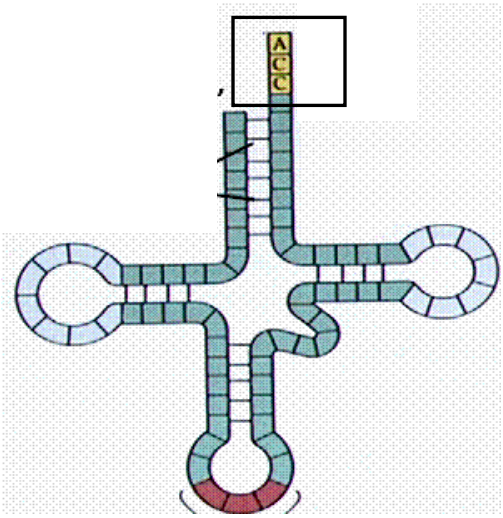


Together with ribosome: **Catalyze** the process of **Translation**

F. RNA

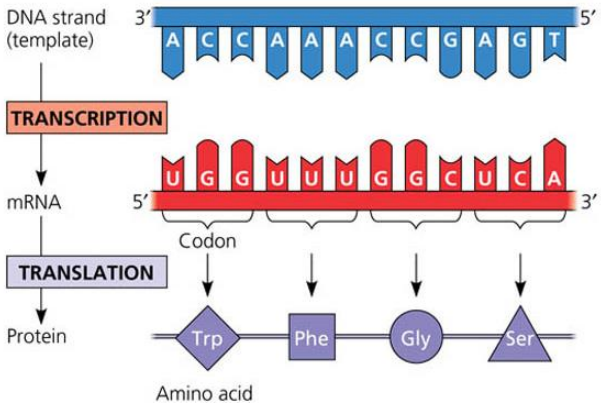
c. **Transfer** RNA (**tRNA**)

Bring **amino acids** to **ribosomes during translation.**



G. Protein Synthesis

1. **Instructions** to make a protein = Specific **section** of **DNA**... A **Gene**!

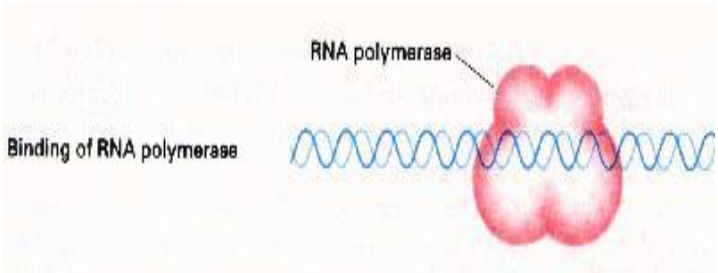


Important Note…

- There is no “trend” in the number or sequence of nucleotides in any given species/domain.
- Example: A sequence can be AAAAAAATTGCGAA in both a Eukaryote & a Prokaryote.
- Redundancy in the genetic code allows for multiple sequence variations that lead to the same/similar product.

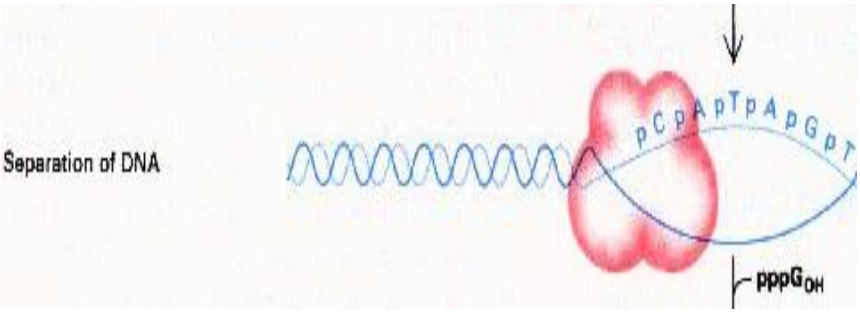
Step 1:Transcription

1. **Transcription Steps**
   a. **RNA** Polymerase **attaches** to the **promoter** = **signal** for where to **start**.



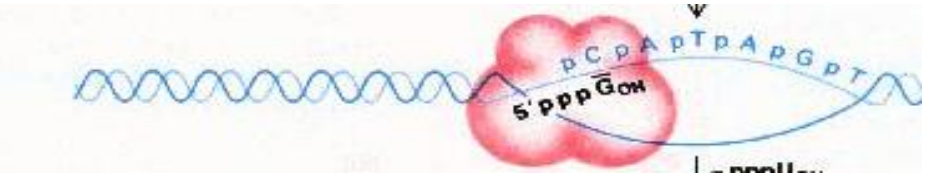
Transcription

b. RNA **Polymerase** "**unwinds**" this portion of **DNA**.



Transcription

c. **RNA** Polymerase "**reads**" the DNA template **sequence from 3' → 5'** to transcribe **mRNA 5' → 3'.**



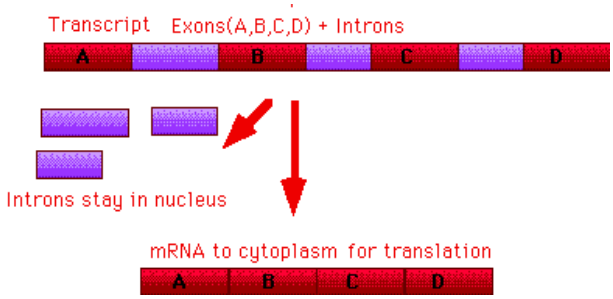
Step 2: RNA Modifications

1. Newly made **mRNA** has information **not needed** for making the protein.

   a. **Introns**: **Not** needed.

   b. **Exons**: **Necessary** protein **instructions**.

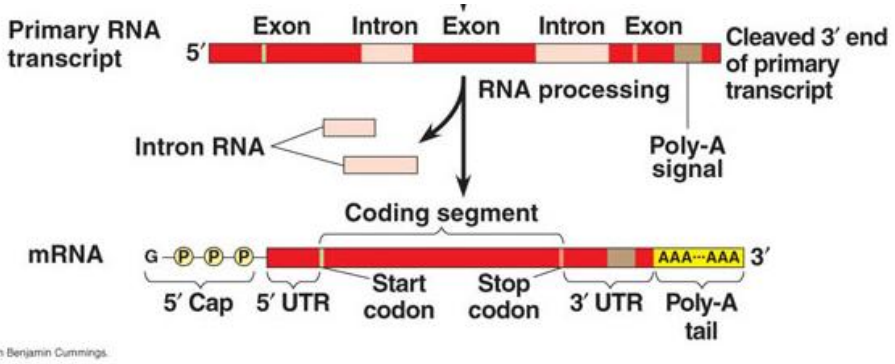
Cut out the "junk" (Introns)



Step 2: RNA Modifications

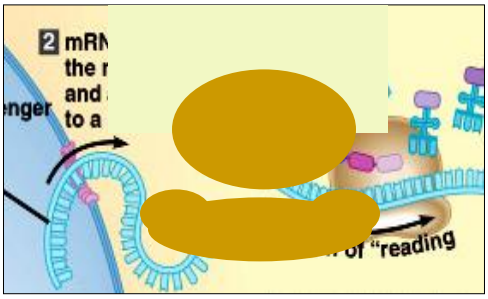
2. Addition of a 3' poly-A tail
3. Addition of a 5' GTP cap

*nuclear export, translation, and stability of mRNA



I. Transport

1. mRNA **leaves** the **nucleus via nuclear pores**, goes into **cytoplasm**.
2. mRNA **attaches** to a **ribosome from its 5' end**.

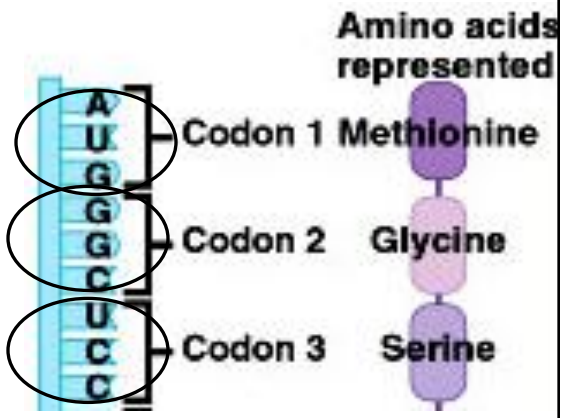


Step 3: Translation

1. Requires a lot of energy to form peptide bonds!
2. Many steps, but 3 main parts:
   1. Initiation
   2. Elongation
   3. Termination

Step 3: Translation

1. Each **amino acid** has a "triplet code" = **Codon**.
2. Each **codon** = **Sequence** of **3 bases**.



The Genetic Code – Redundancy!

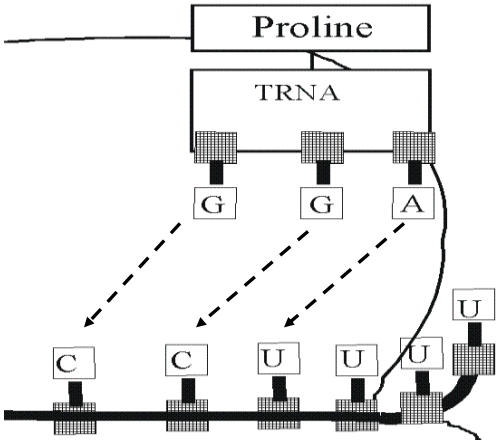
1st letter	Second Letter: U	Second Letter: C	Second Letter: A	Second Letter: G	3rd letter
U	UUU Phe UUC UUA Leu UUG	UCU UCC UCA Ser UCG	UAU Tyr UAC UAA Stop UAG Stop	UGU Cys UGC UGA Stop UGG Trp	U C A G
C	CUU CUC CUA Leu CUG	CCU CCC CCA Pro CCG	CAU His CAC CAA Gln CAG	CGU CGC CGA Arg CGG	U C A G
A	AUU AUC AUA Ile AUG Met	ACU ACC ACA Thr ACG	AAU Asn AAC AAA Lys AAG	AGU Ser AGC AGA Arg AGG	U C A G
G	GUU GUC GUA Val GUG	GCU GCC GCA Ala GCG	GAU Asp GAC GAA Glu GAG	GGU GGC GGA Gly GGG	U C A G

Translation

3. Ribosomes **read** each **codon 5' →3'**

4. **tRNA brings** the matching **amino acid**.

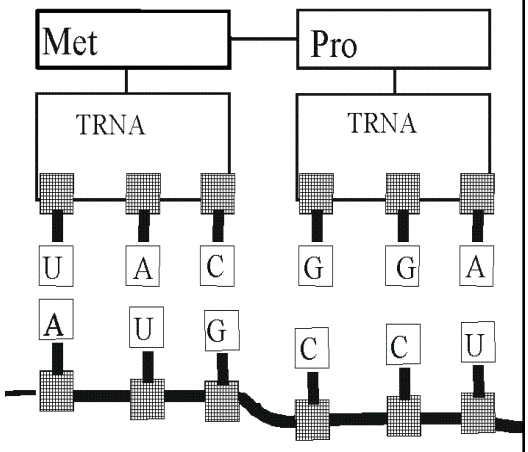
5. Each **tRNA** has an **anticodon** to pair with each **mRNA codon**.



J. Translation

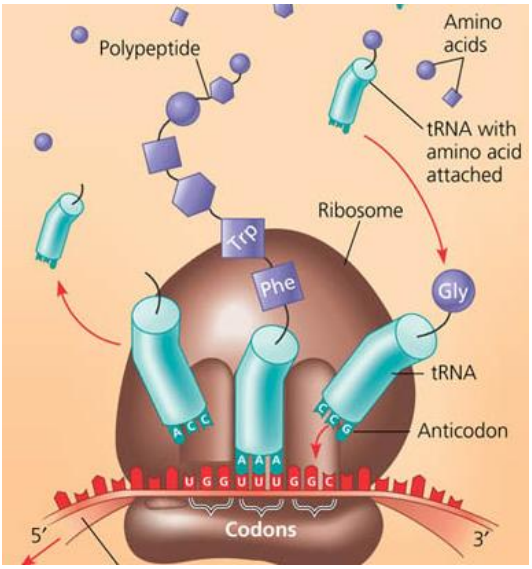
6. **Another** tRNA brings the **next** amino acid.

7. **Peptide Bond** forms **between** the **2** amino acids.



J. Translation

8. Process **repeats** until **entire sequence** is read, and a "stop" codon is reached. The **protein** is **complete**.



Destination of the Protein

- **Free ribosomes** in the **cytoplasm** produce proteins that will function within the cell:
  - Metabolic Enzymes (glycolysis, Krebs cycle)
  - Mitochondria/Chloroplasts/Nucleus proteins
- **Bound ribosomes** on the **ER** produce proteins that will be exported from the cell OR that will become part of the ER or Plasma membrane
  - Transport channels - Receptors

Prokaryotes…

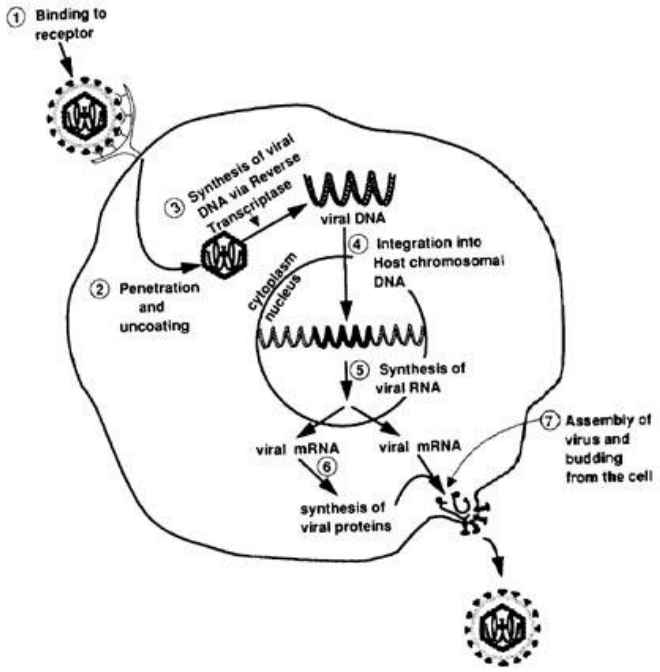
- Transcription & Translation happen in 'lock-step', with transcription coupled directly to translation.
- MUCH LESS regulation of all these processes.
- Otherwise, the sequence of events is similar.

Always an Exception…

- Special scenario: **RETROVIRUSES**
- Alternative sequence: (v = viral h = host)

  vRNA→ **v**DNA →**vh**DNA→**v**RNA →**v**Proteins

  Reverse Transcriptase… quite possibly the scariest yet most amazing enzyme ever to have evolved (in my opinion anyway ☺)
- Human Immunodeficiency Virus



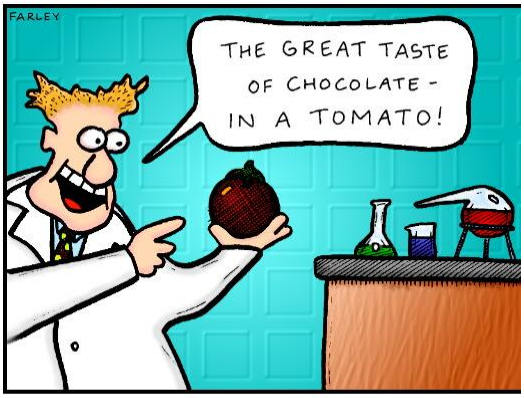
C. Manipulating DNA

1. Genetic **engineering**: **Changing** the DNA **code** of **living** things.

a. Read DNA

b. Edit DNA

c. Put DNA **back into** organisms



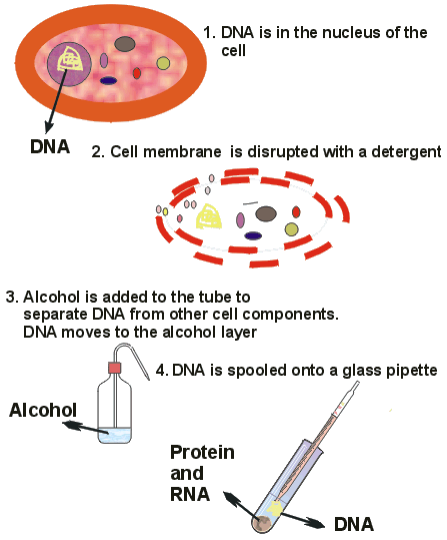
What we have to look forward to from genetic engineering.

C. Manipulating DNA

2. DNA extraction

a. **Break** open **cells.**

b. **Separate** DNA from everything else.

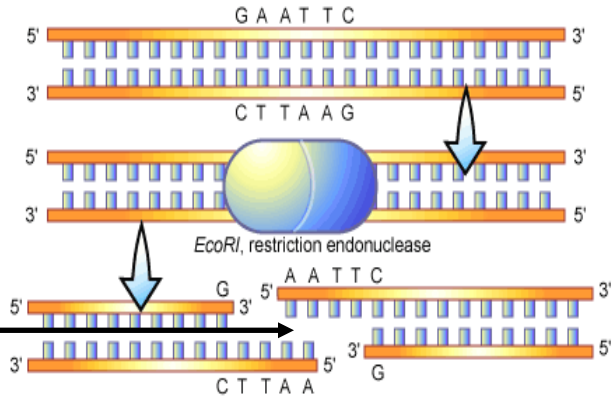


C. Manipulating DNA

3. Cutting DNA

b. Use **restriction enzymes**: Cut DNA at **certain** places.

Cut b/w A & T



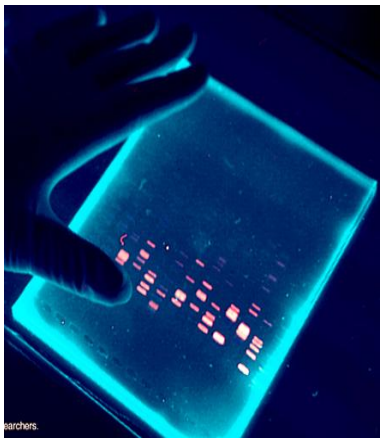
C. Manipulating DNA

4. **Separating** DNA

a. Gel electrophoresis

1. Separates DNA **fragments**.

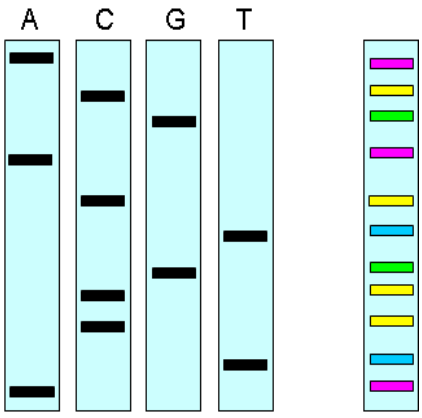
2. Shows **similarities** & **differences** between organisms' **DNA**.



D. Using The DNA Sequence

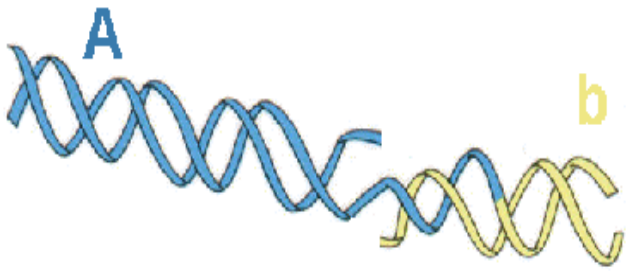
1. **Sequencing** DNA

a. Allows us to **study specific** genes!



D. Using The DNA Sequence

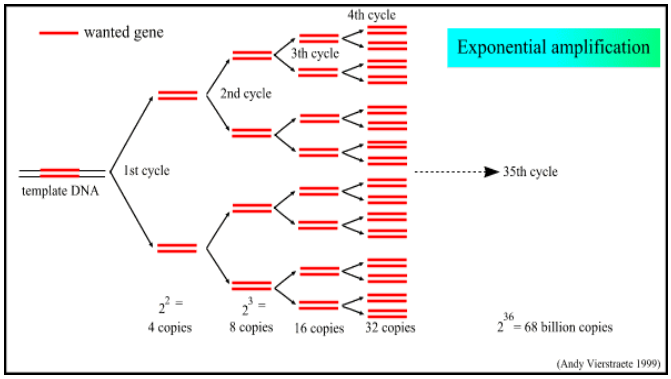
2. **Recombinant** DNA: **Combines** DNA from 2 **different sources**.



D. Using The DNA Sequence

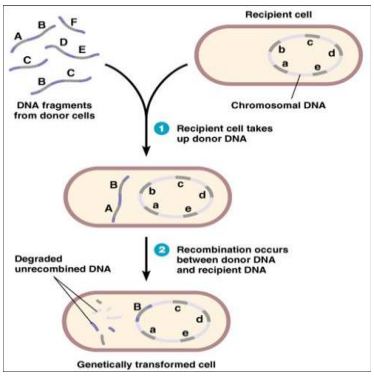
3. Copying DNA

   a. Polymerase **Chain Reaction** (PCR)= Makes many **copies** of a gene.



E. Cell Transformation

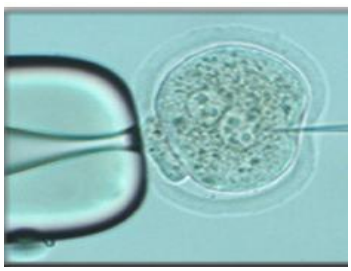
1. Transformation: A cell **takes in** DNA from **outside** the cell. This **new** DNA becomes **part** of the cell's DNA.



F. Applications

1. **Transgenic** organisms: Have **genes** from **other** species.

   a. **Major products** of genetic engineering!



F. Applications

2. Transgenic **microorganisms**
   a. **Insulin**, growth hormones
   b. Fight **cancer**?

F. Applications

3. **Transgenic** plants
   a. Increased **food supply**

F. Applications

4. Transgenic **animals**
   a. Increased food supply
   b. Study **genes**

F. Applications

5. Cloning: Making **genetically identical** cells.

a. **Ian Wilmut** = Cloned a **sheep** in 1997, Dolly!